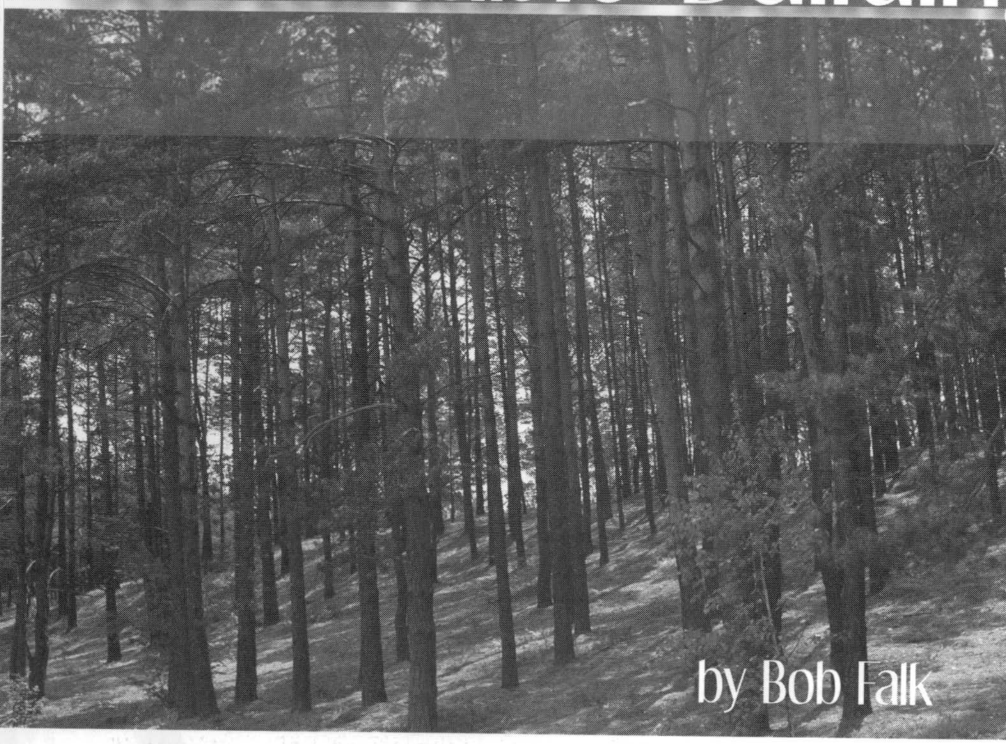
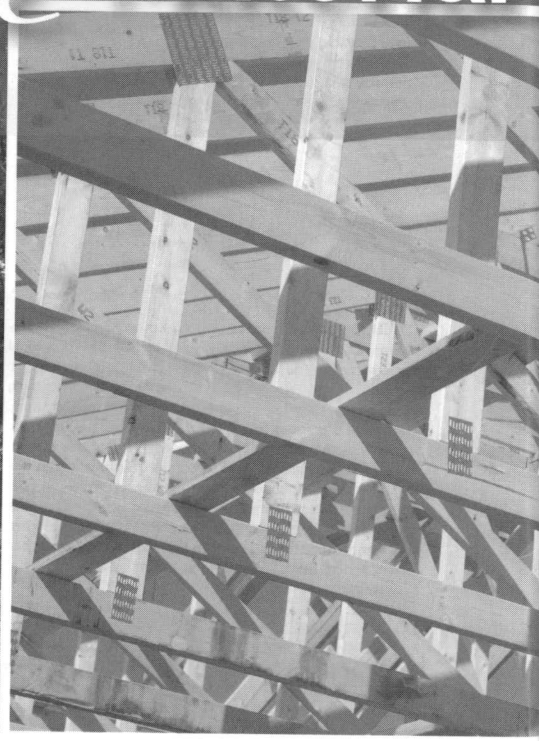
# *Wood as a* Sustainable Building Material





by Bob Falk

## Introduction

Few building materials possess the environmental benefits of wood. It is not only the most widely used building material in the United States but also one with characteristics that make it suitable for a wide range of applications. Efficient, durable, and useful wood products produced from trees range from a minimally processed log at a log-home building site to a highly processed and highly engineered wood composite manufactured in a large production facility.

As with any resource, it is imperative that the raw materials are produced and used to ensure sustainability. One of the greatest attributes of wood is that it is a renewable resource. If sustainable forestry management and harvesting practices are followed, the wood resource will be available forever.

# Wood as a Green Building Material

Over the past decade, the concept of green building[1] has entered the mainstream and the public has become increasingly aware of the potential environmental benefits of this alternative to conventional construction. Much of the focus of green building is on reducing the energy consumption of a building (such as better insulation and more efficient appliances and HVAC systems) and reducing negative human health impacts (such as controlled ventilation and humidity to reduce mold growth). Choosing building materials that exhibit positive environmental attributes is also a major area of focus. Wood has many positive characteristics, including low embodied energy, low carbon impact, and sustainability. These characteristics are important because in the United States, slightly more than half of the wood harvested in the forest is used in construction.

## Embodied Energy

A positive characteristic of wood is its low embodied energy. Embodied energy refers to the quantity of energy required to harvest, mine, manufacture, and transport to the point of use a material or product. Wood, a material that requires a minimal amount of energy-based processing, has a low level of embodied energy relative to many other materials used in construction (e.g., steel, concrete, aluminum, or plastic).

The sun provides the energy to grow the trees from which wood products are produced; fossil fuels are the primary energy source required in the manufacture of steel and concrete. Over half of the energy consumed in manufacturing wood products in the United States is from biomass (or bioenergy) which is typically produced from tree bark, sawdust, and by-products of pulping in papermaking processes. The U.S. wood products industry is the nation's leading producer and consumer of bioenergy, accounting for about 60 percent of all production (**Table 1**) (Murray et al. 2006, EPA 2007). Solid wood products have the lowest level of embodied energy; wood products requiring additional processing steps (e.g., plywood, engineered wood products, flake-based products) require more energy to produce but the requirement is significantly less than their non-wood counterparts.

In some plantation forest operations, added energy costs may be associated with the use of fertilizers, pesticides, and greenhouses to grow tree seedlings. During the harvesting operation, energy is used to power harvesting equipment and for transporting logs to the mill. Lumber milling processes that consume energy include log and lumber transport, sawing, planing, and wood drying. Kiln-drying is the most energy-consumptive process of lumber manufacture; however, bioenergy from a mill's waste wood is often used to heat the kilns. Unlike the burning of fossil fuels, the use of bioenergy for fuel is considered to be carbon neutral. Also, advances in kiln technologies over the past few decades have significantly reduced the amount of energy required for wood drying. Overall, the production of dry lumber requires about twice the energy of producing green (undried) lumber.

*Table 1. — Wood products industry fuel sources.*[a]

| Fuel source | Proportion used (%) |
|---|---|
| Net electricity | 19 |
| Natural gas, LPG, etc. | 16 |
| Fuel oil | 3 |
| Other (primarily biomass) | 61 |

[a]Source: EPA 2007.

The Consortium for Research on Renewable Industrial Materials (CORRIM) determined that different methods of forest management affect the level of carbon sequestration in trees (Perez-Garcia et al. 2005). It concluded that shorter rotation harvests can sequester more total carbon than longer rotation harvests.

CORRIM also calculated differences in the energy consumed and environmental impacts associated with resource extraction, materials production, transportation, and disposal of homes built using different materials and processes. These calculations show that the energy consumed in the manufacture of building materials (mining iron and coal for steel or harvesting wood for lumber) and the construction of a steel-framed house in Minneapolis was 17 percent greater than for a wood-framed house (Lippke et al. 2004). The difference is even more dramatic if the use of bioenergy in the manufacture of wood products is taken into consideration. By this comparison, the steel-framed house uses 281 percent more non-bioenergy than the wood-framed house (Perez-Garcia et al. 2005). The global warming potential, air emission index, and water emission index are all higher for steel construction than for wood construction (**Table 2**).

These analyses indicate that the amount of energy necessary for producing wood products is much less than comparable products made from other materials. If wood is substituted for these other materials (assuming similar durability allows equal substitution), energy is saved and emissions avoided each time wood is used, giving it a distinct environmental advantage over these other materials (Bowyer et al. 2008).

[1] Green building is defined as the practice of increasing the efficiency with which buildings use resources while reducing the impacts of the building on human health and the environment—through better siting, design, material selection, construction, operation, maintenance, and removal—over the complete building life cycle.

*Table 2. — Environmental performance indices for above-grade wall designs in residential construction.*[a]

| | Wood frame | Steel frame | Difference | Change[b] (%) |
|---|---|---|---|---|
| **Minneapolis design** | | | | |
| Embodied energy (GJ) | 250 | 296 | 46 | +18 |
| Global warming potential ($CO_2$ kg) | 13,009 | 17,262 | 4,253 | +33 |
| Air emission index (index scale) | 3,820 | 4,222 | 402 | +11 |
| Water emission index (index scale) | 3 | 29 | 26 | +867 |
| Solid waste (total kg) | 3,496 | 3,181 | –315 | –0.9 |
| **Atlanta design** | | | | |
| Embodied energy (GJ) | 168 | 231 | 63 | +38 |
| Global warming potential ($CO_2$ kg) | 8,345 | 14,982 | 6,637 | +80 |
| Air emission index (index scale) | 2,313 | 3,373 | 1,060 | +46 |
| Water emission index (index scale) | 2 | 2 | 0 | 0 |
| Solid waste (total kg) | 2,325 | 6,152 | 3,827 | +164 |

[a] Lippke et al. 2004.

[b] % change = [(Steel frame – Wood frame)/(Wood frame)] X 100.

## Carbon Impact

The role of carbon in global climate change and its projected negative impact on ecosystem sustainability and the general health of the planet has never been more elevated in the public's consciousness.

Forests play a major role in the Earth's carbon cycle. The biomass contained in forests and other green vegetation affects the carbon cycle by removing carbon from the atmosphere through the photosynthesis process. This process converts carbon dioxide and water into sugars for tree growth and releases oxygen into the atmosphere:

$$\text{energy (sunlight)} + 6H_2O + 6CO_2 \rightarrow C_6H_{12}O_6 + 6O_2$$

A substantial amount of carbon can be sequestered in trees, forest litter, and forest soils. Approximately 26 billion metric tonnes of carbon is sequestered within standing trees, forest litter, and other woody debris in domestic forests and another 28.7 billion tonnes in forest soils (Birdsey and Lewis 2002). According to Negra et al. (2008), between 1995 and 2005 the rate of carbon sequestration in U.S. forests was about 150 million tonnes annually (not including soils), a quantity of carbon equivalent to about 10 percent of total carbon emissions nationally.

Unfortunately, deforestation in tropical areas of the world is responsible for the release of stored carbon, and these forests are net contributors of carbon to the atmosphere. Tropical deforestation is responsible for an estimat-

*Table 3. — Net carbon emissions in producing a tonne of various materials.*

| Material | Net carbon emissions (kg C/t)[a,b] | Near-term net carbon emissions including carbon storage within material (kg C/t)[c,d] |
|---|---|---|
| Framing lumber | 33 | –457 |
| Medium-density fiberboard (virgin fiber) | 60 | –382 |
| Brick | 88 | 88 |
| Glass | 154 | 154 |
| Recycled steel (100% from scrap) | 220 | 220 |
| Concrete | 265 | 265 |
| Concrete[e] | 291 | 291 |
| Recycled aluminum (100% recycled content) | 309 | 309 |
| Steel (virgin) | 694 | 694 |
| Plastic | 2,502 | 2,502 |
| Aluminum (virgin) | 4,532 | 4,532 |

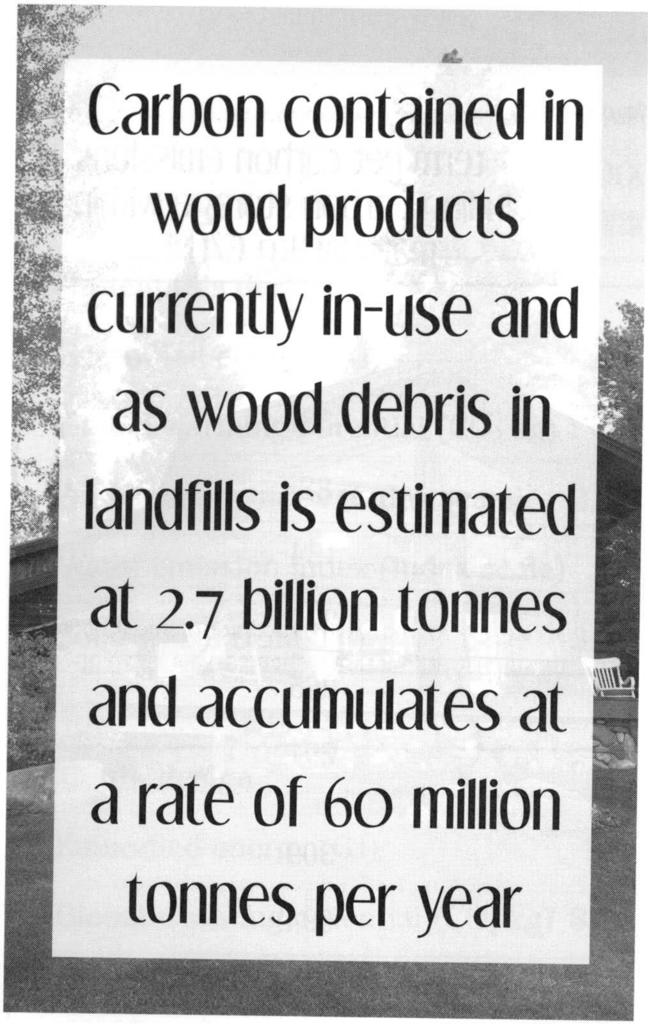
[a] Values are based on life-cycle assessment and include gathering and processing of raw materials, primary and secondary processing, and transportation.
[b] Source: EPA 2006.
[c] From Bowyer et al. 2008; a carbon content of 49% is assumed for wood.
[d] The carbon stored within wood will eventually be emitted back to the atmosphere at the end of the useful life of the wood product.
[e] Derived based on EPA value for concrete and consideration of additional steps involved in making blocks.

ed 20 percent of total human-caused carbon dioxide emissions each year (Schimel et al. 2001).

Carbon in wood remains stored until the wood deteriorates or is burned. When burned, wood immediately releases its carbon. A tree that remains in the forest and dies releases a portion of its carbon back into the atmosphere as the woody material decomposes. If the tree is sawn into lumber, the lumber most often is used in building construction (the building industry is the largest user of sawn wood in the United States) and the carbon contained in that product is sequestered for the life of the building. At the end of a building's life, wood can be recovered for re-use in another structure, chipped for use as fuel or mulch, or sent to a landfill (usual fate). If landfilled, burned, or mulched, stored carbon is released when the wood decomposes, essentially the reverse process of photosynthesis:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

Carbon contained in wood products currently in-use and as wood debris in landfills is estimated at 2.7 billion tonnes (Heath and Skog 2004) and accumulates at a rate of 60 million tonnes per year (Heath and Smith 2004). Much of the carbon contained within wood products resides in the nation's housing stock, estimated at 116 million units in 2000. As shown in **Table 3**, carbon emitted to produce a tonne of concrete is about eight times that emitted to produce a tonne of framing lumber. A similar comparison for



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steel indicates that its production emits about 21 times as much carbon as an equal weight of framing lumber.

Moreover, because wood products have a low level of embodied energy compared to other building products and because wood is one-half carbon by weight, wood products actually can be carbon negative (Bowyer et al. 2008).

Comparisons of the environmental impact of various wood products also have been made using life cycle analysis software (Calkins 2009). The more processing involved in the manufacture of wood products (such as flaking, veneer cutting, adding heat for pressing, gluing, kiln-drying), the greater the impact on energy use, solid waste production, pollution production, and global warming potential (carbon).

## Sustainability

Unlike metals and fossil fuel-based products (such as plastics), the forest resource is renewable, and with proper management a flow of wood products can be maintained forever. The importance of forest-based products to the U.S. economy and standard of living is hard to overemphasize—half of all of the major industrial raw materials used in the United States are derived from forests. The sustainability of this resource, however, requires forestry and harvesting practices that ensure the long-term health and diversity of the forests. Unfortunately, sustainable practices have not been always applied in the past, nor are they universally applied around the world today. Architects, product designers, material specifiers, and homeowners are increasingly asking for certified building products that are from a sustainable source. For the forest products sector, the result of this demand has been the formation of forest certification programs. While all certification programs emphasize resource sustainability, some place emphasis on issues of biodiversity, habitat protection, and indigenous peoples' rights in land management plans.

## Forest Certification Programs

More than 50 different forest certification systems in the world today represent nearly 700 million acres of forestland and 15,000 companies involved in producing and marketing certified products. These programs represent about 8 percent of the global forest area and 13 percent of managed forests. From 2007 to 2008, the world's certified forest area grew by nearly 9 percent. North America has certified more than 33 percent of its forests and Europe more than 50 percent of its forests; however, Africa and Asia have certified less than 0.1 percent.

Approximately 80 to 90 percent of the world's certified forests are located in the northern hemisphere, where two-thirds of the world's roundwood is produced (UNECE 2008). In North America, five major certification systems are used:

- Forest Stewardship Council (FSC),
- Sustainable Forestry Initiative (SFI),
- American Tree Farm System (ATFS),
- Canadian Standards Association (CSA), and
- Programme for the Endorsement of Forest Certification (PEFC) schemes.

In terms of forest acreage under certification, FSC and SFI dominate in the United States. These two systems evolved from different perspectives of sustainability. FSC's guidelines focus on preserving natural systems while allowing for careful harvest, whereas SFI's guidelines encourage fiber productivity while allowing for conservation of resources (Howe et al. 2004). The growing trends in green building are helping drive certification in the construction market in the United States.

### Forest Stewardship Council (FSC)

FSC is an independent, non-governmental, not-for-profit organization established to promote responsible management of the world's forests. It is probably the most well-known forest certification program worldwide. More than 280 million acres of forest in over 79 countries worldwide are certified to FSC standards. The FSC program includes two types of certification. Forest Management

Certification applies FSC standards of responsible forestry to management of the forest land. Chain-of-Custody (COC) certification ensures that forest products with the FSC label can be tracked back to the certified forest from which they came. More than 14,800 COC certifications are in use by FSC members. FSC has certified 18 certification bodies around the world. Six have offices located in the United States, including the non-profit Rainforest Alliance's SmartWood program and the for-profit Scientific Certification Systems. Both of these organizations provide up-to-date lists of FSC-certified wood suppliers in the United States. The United States Green Building Council (USGBC) acknowledges use of FSC-certified wood and requires a minimum of 50 percent certified wood on a LEED (Leadership in Energy and Environmental Design) Green Building Rating System project (USGBC 2005). At this time, the USGBC does not recognize other certification systems.

## Sustainable Forestry Initiative (SFI)

SUSTAINABLE FORESTRY INITIATIVE

The Sustainable Forestry Initiative was established by the American Forest & Paper Association (AF&PA) in 1994 and currently certifies over 177 million acres in the United States and Canada. As of August 2009, 719 SFI COC certificates have been issued for complete chain-of-custody. This program has a strong industry focus and has been adopted by most of the major industrial forest landowners in the United States. It is based on the premise that responsible forest practices and sound business decisions can co-exist.

## American Tree Farm System (ATFS)

Established in 1941, the American Tree Farm System, a program of the American Forest Foundation's Center for Family Forests, is the oldest forest certification program. ATFS focuses on private family forest landowners in the United States. Currently, ATFS has certified 24 million acres of privately owned forestland of 90,473 family forest owners in 46 states. ATFS has established standards and guidelines which property owners must meet to become a Certified Tree Farm. Under these standards and guidelines, private forest owners must develop a management plan based on strict environmental standards and pass an inspection by an ATFS volunteer forester every five years.

## Canadian Standards Association (CSA)

The Canadian Standards Association, a non-profit organization, has developed over 2,000 standards for a variety of industries. CSA first published Canada's National Standard for Sustainable Forest Management (SFM) CAN/CSA-Z809 in 1996. The SFM program has four components: the SFM Standard itself, a COC program, product marking, and the CSA International Forest Products Group, which promotes the program. The CSA Standard has been adopted by the major industrial forestland managers in Canada. AF&PA has also accepted the CSA Standard as the "functional equivalent of the SFI Standard" (Fernholz et al. 2005). As of June 2007, approximately 60 percent (198 million acres) of Canadian forests were certified under the CAN/CSA-Z809 SFM Standard.

## Programme for the Endorsement of Forest Certification (PEFC) schemes

The multitude of certification programs with competing standards and claims has made it difficult for land managers, members of the wood industry, and consumers to determine which certification program fits their needs (Fernholz et al. 2004). The Programme for the Endorsement of Forest Certification schemes was developed to address this issue and serves as an umbrella endorsement system that provides international recognition for national forest certification programs. Founded in 1999, PEFC represents most of the world's certified forest programs and the

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production of millions of tons of certified timber. The CSA, SFI, and ATFS programs have received official PEFC endorsement.

## Additional Information

Helpful online tools provide more information and data on forest certification, including the Forest Certification Resource Center (*www.metafore.org*), which identifies forests, manufacturers, distributors, importers, and retailers certified under the FSC, SFI, and CSA programs. The database is searchable by product, location, and certification system. Each individual certification program also offers information about certificates and certified products at its website.

Another helpful resource is the Forest Products Annual Market Review (*www.unece.org*), which provides general and statistical information on forest products markets in the United Nations Economic Commission for Europe (UNECE) and covers the regions of Europe, North America, and the Commonwealth of Independent States.

## Conclusions

It's clear that the green building movement is here to stay and will undoubtedly grow in the future. This can be good for the wood industry, because there is a positive and convincing story to tell about wood as a sustainable and environmentally preferable material. By providing the green building community with science-based facts about sustainability, embodied-energy, and carbon impact, wood can stand out as the *greenest* of building materials.

## Note to Readers

This article will become Chapter 1 of the U.S. Forest Service, Forest Products Laboratory's 100th Anniversary edition of the *Wood Handbook: Wood as an Engineering Material*, scheduled for publication in 2010.

**The author is a Research Engineer, U.S. Forest Service, Forest Products Laboratory, Madison, WI.**

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